Improved Geospatial Scenarios for Commercial Marine Vessels

Prepared for the California Air Resources Board
California Environmental Protection Agency
Contract No.: 07-320

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Based on original work of Dr. Chengfeng Wang

Presented at the ARB Air Pollution Seminar Series
7 June 2011

Review of ARB Project Objectives

1. Provide geographically resolved vessel specific estimates of commercial marine vessel (CMV) emissions in North American waters that are consistent with earlier studies for the California Air Resources Board (ARB)

2. Apply vessel-specific growth trends describing trade and energy requirements for North American cargo and passenger vessels
   a) Unconstrained business as usual (BAU) estimates for 2010 (prior to international sulfur regulations)
   b) Lower-growth 2020 scenario assuming International Maritime Organization (IMO)-compliant reductions in global fuel sulfur

ARB focus on West Coast U.S. coastlines;

SECA Team focus … North America

Key insights

- ***Obvious:*** Fastest growing routes show greatest fuel use increase in and least in Sox reductions from lower-sulfur fuels
- ***Expected:*** Container shipping contributes the greatest amount of emissions and uses the most fuel among all ship types.
  - Due to higher installed power associated with liner shipping of containerized goods
  - Due to the nature of consumption of imported goods in North American communities.
- ***Detail:*** Containerized shipping activity increases from roughly 35% to nearly 60% of total emissions by 2020, under high-growth scenarios.
  - Under lower-growth scenarios containerships still increase activity faster than other ship types, contributing more than 40% to 2020 totals.
- ***Implication:*** Containerized shipping is intrinsically intermodal (connecting with rail and road); therefore, international trade linked with domestic goods movement decisions.

VESSEL-SPECIFIC BASELINE

North American CMV Emissions

Building on very good foundation
July 2007: Previous work summary

- Beginning with 2002 results:
  - ~47 Mtons fuel and ~2.4 Mtons of SO_2 globally
  - ~30 Mtons fuel, ~1.6 Mtons SO_2 in project domain
- Growth trends for North America ~5.9% per year

Ship emissions growth rates are faster than GDP

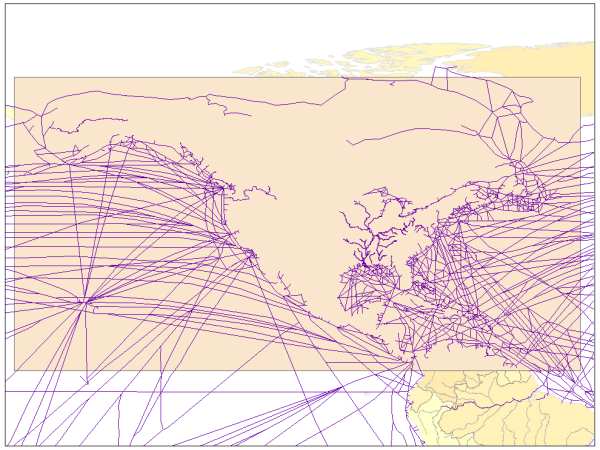
Future emissions with IMO-compliant SECA will be greater than base year emissions in 2002.

- Redo vessel-specific 2002 results:
  - ~45 Mtons fuel and ~2.3 Mtons of SO_2 globally
  - ~33 Mtons fuel, ~1.7 Mtons SO_2 in project domain

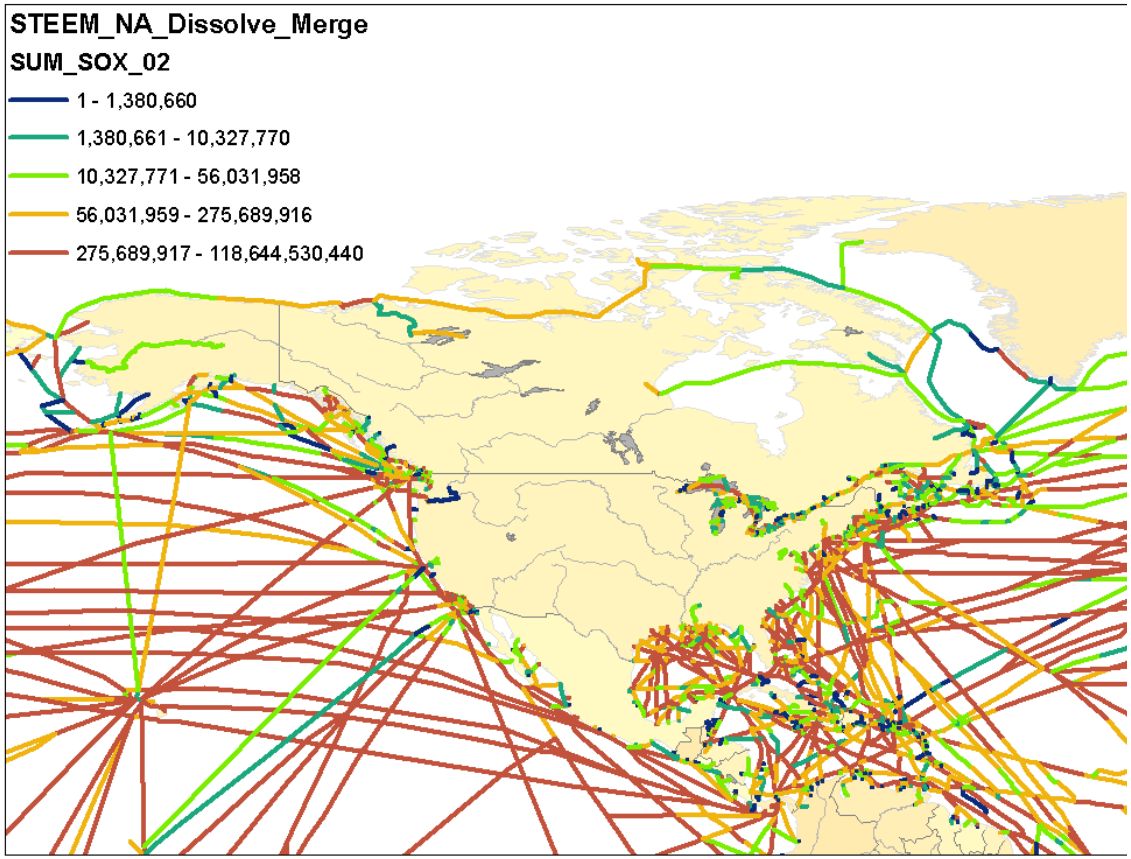
Trimmed emissions to North America region (ARB-defined study domain)

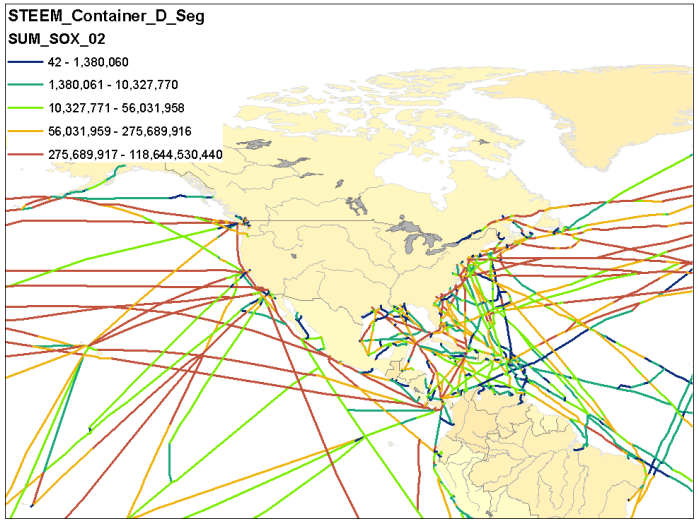
metric tons	NOx	SOx	CO_2	HC	PM	CO	Fuel Use
Bulk Carrier	560,000	330,000	19,400,000	19,000	47,000	44,000	6,430,000
Container	1,030,000	610,000	35,810,000	34,000	86,000	80,000	11,870,000
Fishing	1,100	900	54,000	40	120	90	18,000
General Cargo	250,000	150,000	8,550,000	8,000	21,000	19,000	2,840,000
Miscellaneous	46,000	36,000	2,220,000	1,600	4,900	3,600	720,000
Passenger	210,000	130,000	7,430,000	7,000	18,000	17,000	2,510,000
Reefer	62,000	36,000	2,150,000	2,100	5,000	4,800	720,000
RO-RO	240,000	140,000	8,460,000	8,000	20,000	19,000	2,810,000
Tanker	490,000	290,000	17,160,000	17,000	41,000	39,000	5,690,000
Domain Total	2,890,000	1,720,000	101,230,000	100,000	240,000	230,000	33,600,000

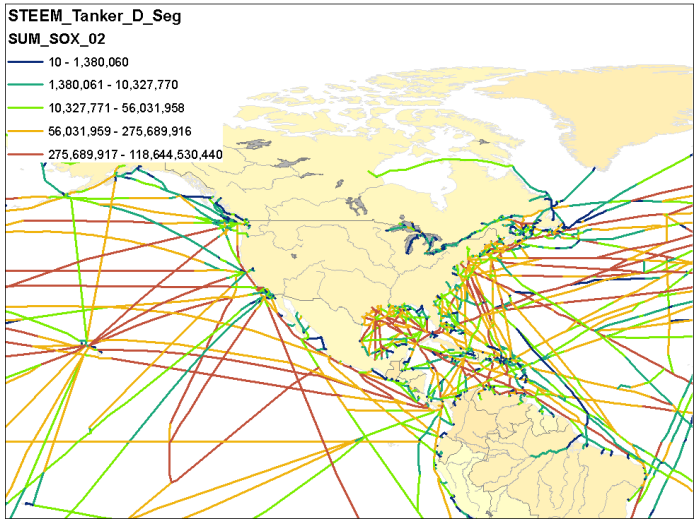
Vessel Type	Average Percent in Domain
Bulk Carrier	64%
Container	75%
Fishing	64%
General Cargo	75%
Miscellaneous	86%
Passenger	97%
Reefer	71%
RO-RO	80%
Tanker	75%
Domain Percent	75%



2002 Results Visualized







Units: grams/year by segment.

VESSEL-SPECIFIC FORECASTS

Additional Growth Scenarios

We developed additional growth scenarios at ARB request

	Scenario 1	Scenario 2
Vessel Specific Growth Rates	Composite 5.9% to 2020	2020 using IMO-hi Scenario
Bulk	1.5%	2.3%
Container	11.0%	4.6%
Fishing	0.1%	0.1%
General	1.0%	1.3%
Miscellaneous	0.5%	1.0%
Passenger	6.0%	1.7%
Reefer	9.0%	4.6%
RO-RO	6.0%	4.6%
Tanker	2.0%	2.0%

Vessel Type	Percent Distillate	Composite SOx Aux. EF	Fuel Use	NOx	SOx	CO_2	HC	PM	CO
Bulk	29%	9.98	206	17.9	10.6	622.9	0.6	1.5	1.4
Container	29%	9.98	206	17.9	10.6	622.9	0.6	1.5	1.4
Fishing	100%	4.3	221	14	11.5	677	0.5	1.5	1.1
General	29%	9.98	206	17.9	10.6	622.9	0.6	1.5	1.4
Miscellaneous	100%	4.3	221	14	11.5	677	0.5	1.5	1.1
Passenger	8%	11.66	206	17.9	10.6	622.9	0.6	1.5	1.4
Reefer	29%	9.98	206	17.9	10.6	622.9	0.6	1.5	1.4
RO-RO	29%	9.98	206	17.9	10.6	622.9	0.6	1.5	1.4
Tanker	29%	9.98	206	17.9	10.6	622.9	0.6	1.5	1.4

Adjusted to replicate sulfur limits

1. Data from composite EF data reported in prior SEESM study [7]

Vessel Type	Percent Distillate	Composite SOx Aux. EF	Fuel Use	NOx	SOx	CO_2	HC	PM	CO
Bulk	29%	4.21	206	15.38	1.96	622.9	0.6	0.40	1.4
Container	29%	4.21	206	15.38	1.96	622.9	0.6	0.40	1.4
Fishing	100%	4.21	221	14.00	1.96	677	0.5	0.40	1.1
General	29%	4.21	206	15.38	1.96	622.9	0.6	0.40	1.4
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Emissions rates and Fuel use rates in g/kWh

We produced future power estimates

		Scenario 1		Scenario 2	
Vessel Type	Sum of 2002 power	Sum of 2010 power	Sum of 2020 power	Sum of 2020 power	Sum of 2010 power
Bulk Carrier	48,369	50,578	58,698	65,337	51,845
Container	76,720	104,924	297,923	138,177	87,877
Fishing	117	117	118	118	117
General Cargo	18,182	18,732	20,692	21,533	18,905
Miscellaneous	3,740	3,797	3,991	4,252	3,853
Passenger	12,325	14,679	26,288	15,325	12,960
Reefer	4,811	6,230	14,748	8,664	5,510
RO-RO	16,987	20,231	36,231	30,594	19,457
Tanker	36,701	38,947	47,476	47,356	38,924

Total Emissions from OGV Serving North American (not limited to North American domain for deliverable)

- Updated inventory for 2002 closely agrees
  - Fuel use globally from this traffic ~45 Mtons
  - SOx emissions ~2.3 Mtons
- Estimates for under BAU (prior) growth
  - 2010: Fuel use ~53 Mtons; SOx ~2.7 Mtons
  - 2020: Fuel use ~105 Mtons; SOx ~1 Mtons
- Estimates for under lower-growth (IMO)
  - 2010: Fuel use ~50 Mtons; SOx ~2.5 Mtons
  - 2020: Fuel use ~68 Mtons; SOx ~0.7 Mtons

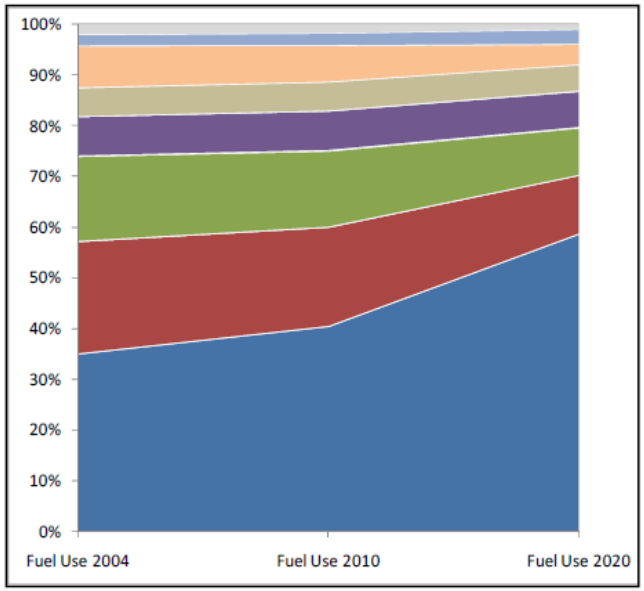
Results within North American domain

- Updated inventory for 2002 closely agrees
  - Fuel use from this traffic ~33 Mtons
  - SOx emissions ~1.7 Mtons

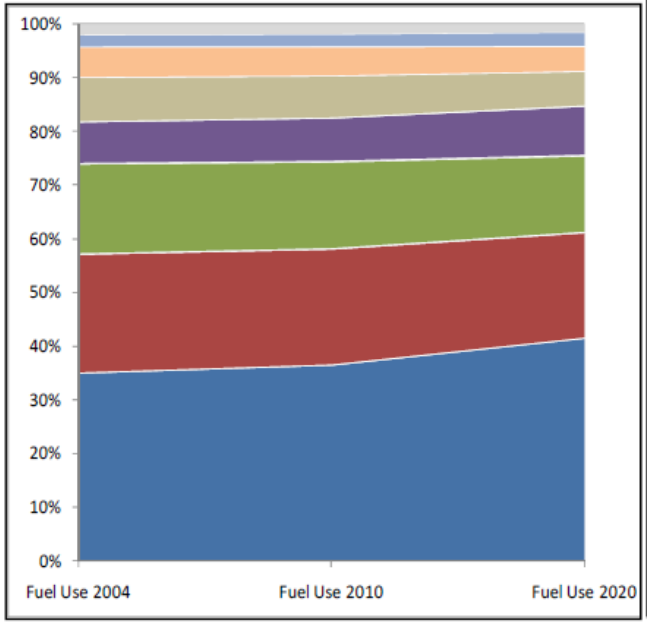
- Estimates for under BAU (prior) growth
  - 2010: Fuel use ~40 Mtons; SOx ~2 Mtons
  - 2020: Fuel use ~79 Mtons; SOx ~0.8 Mtons

Vessel-type specific percent contributions to using

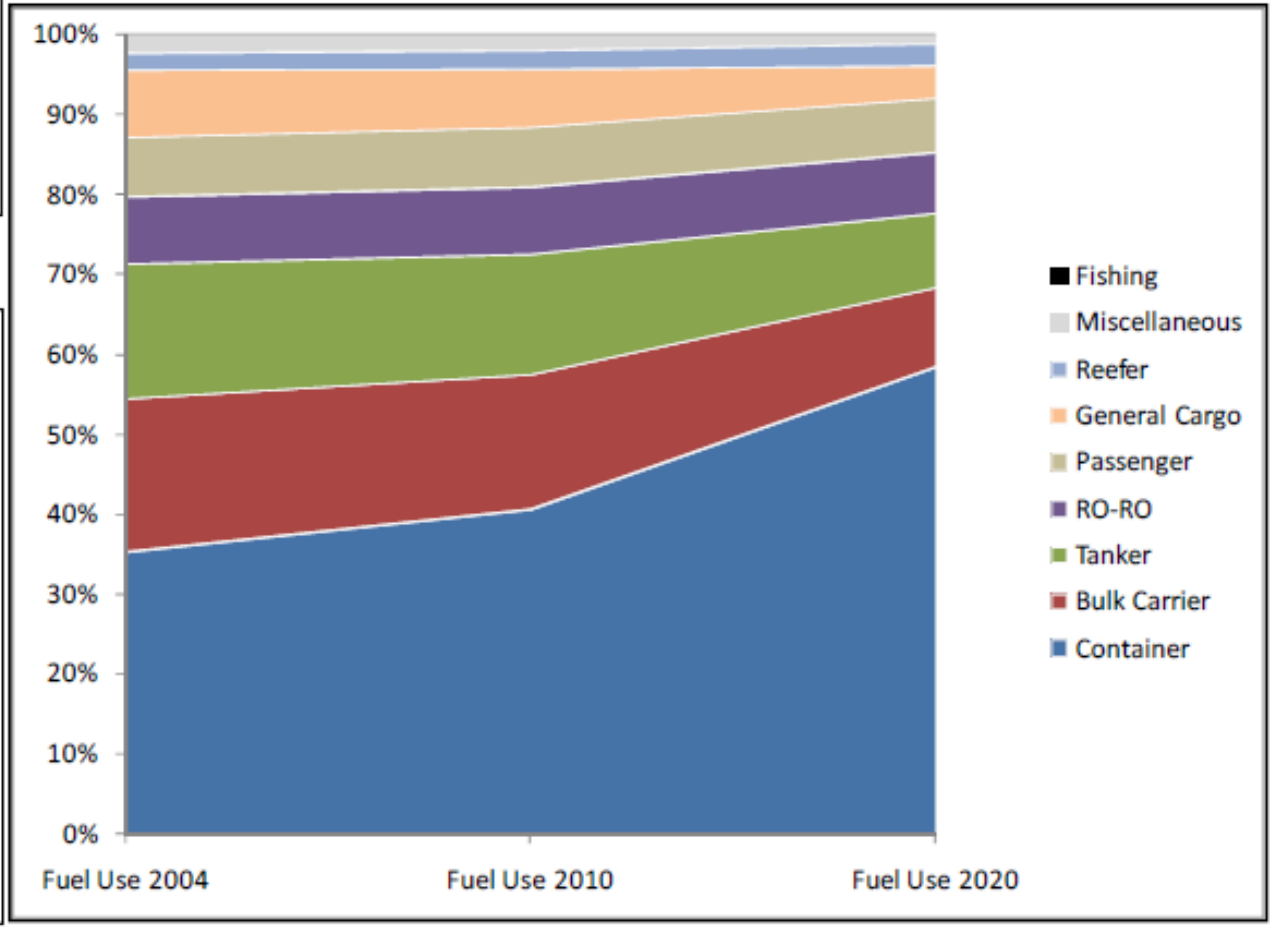
a) global domain and Scenario 1;
b) global domain and Scenario 2; and
c) North American domain and Scenario 1.



(a)



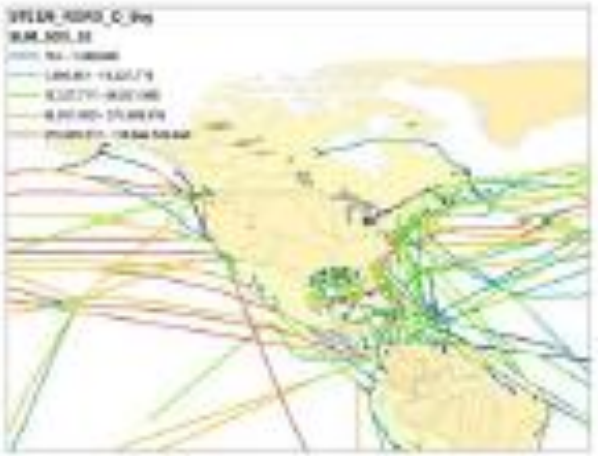
(b)



(c)

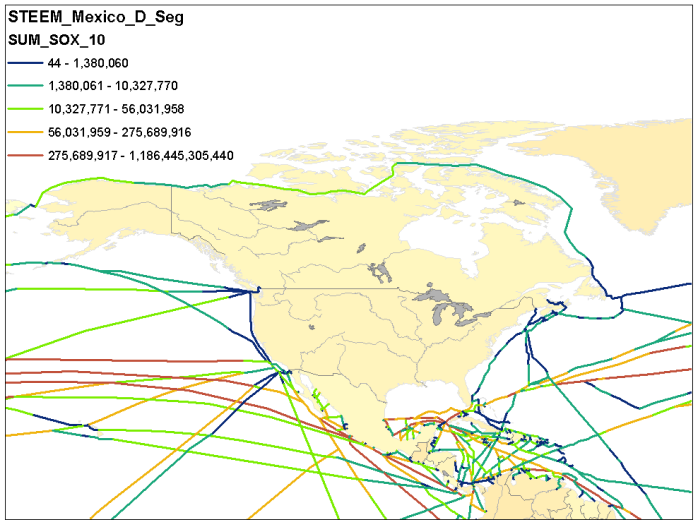


Units: grams/year by segment.



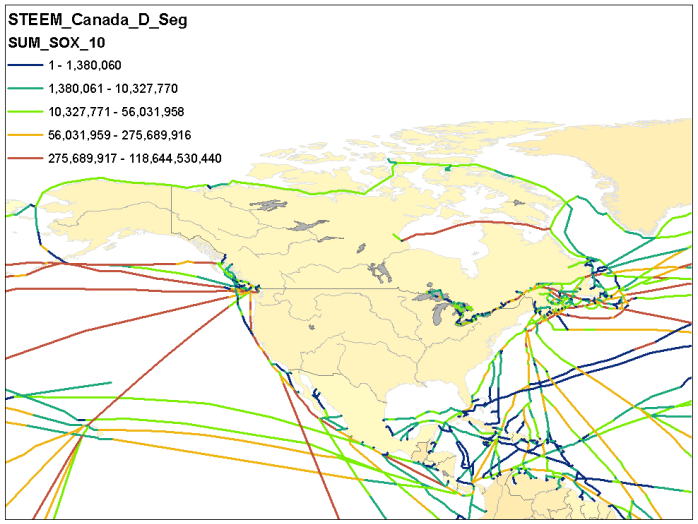
VISUALIZATION OF FORECASTS

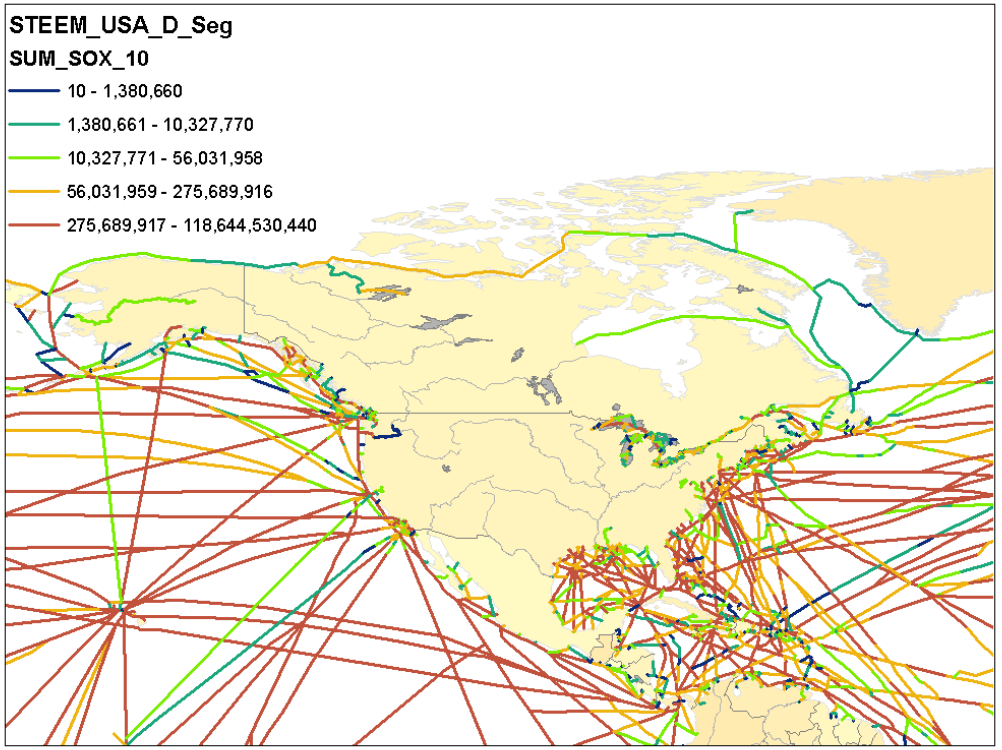


Vessel-type specific percent contributions to using

a) global domain and Scenario 1;
b) global domain and Scenario 2; and
c) North American domain and Scenario 1.

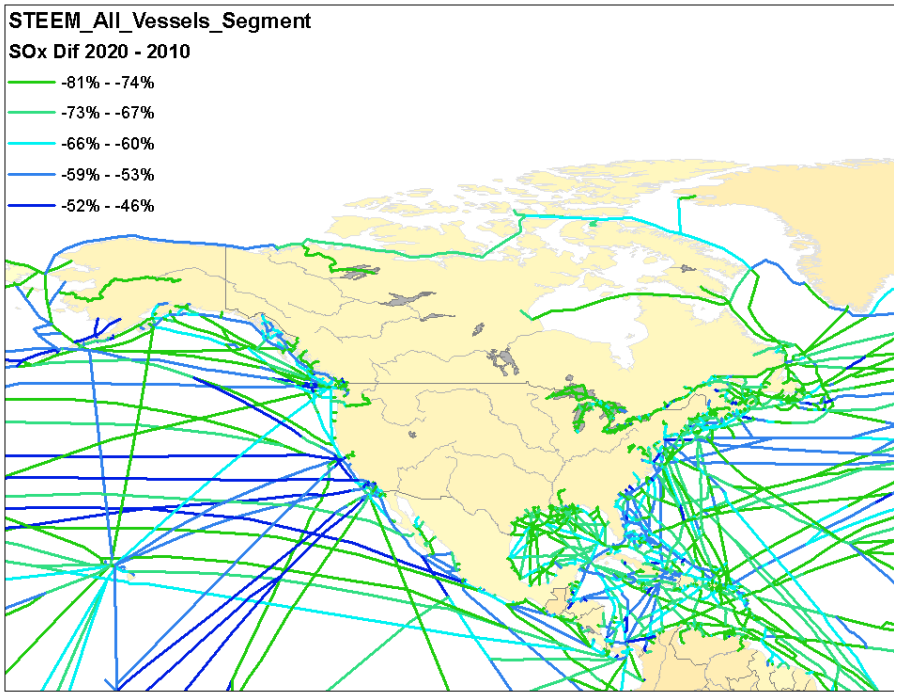
Units: grams/year by segment.



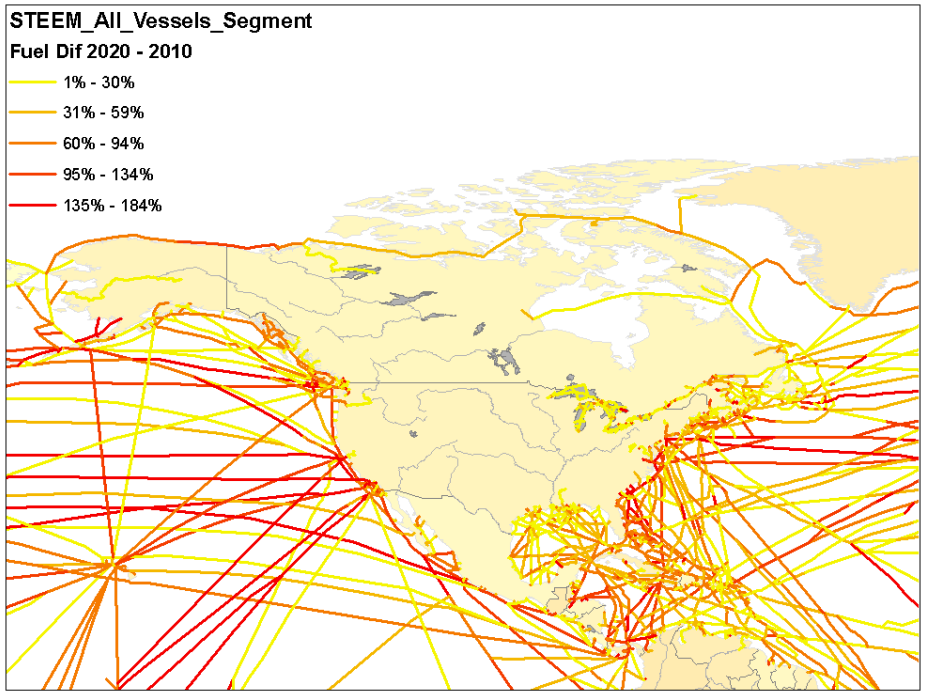


Implications of Forecasts (ECA-ish)

2020 change in SOx (reduction)



2020 change in Fuel Use (increase)



SUMMARY

Conclusions

- Expected change in patterns of shipping result solely from asymmetric growth among vessel types.

- Intensities of future emissions offshore North American may contribute to shifting sources of transport of air pollution.

- On average, ships serving North America spend ~75% in domain
  - Passenger, miscellaneous, and RO-RO ships spend more time within the region and bulk carriers and fishing vessels spend less time in domain
  - Could indicate which vessel groups have similar cost-effective controls

Other results

Strengths

- Revealed vessel-specific monthly variation exists
- Enables other scenarios
- Facilitates independent comparisons
- Shapefiles delivered

Limitations

- Did not reproduce STEEM buffered segments
- Did not re-run O-Ds, and some matches redundant
  - Difference <4% but not exact
- Segment locations could improve or be updated

Questions?